

Lake Michigan Potential Damages Study

In October 1996, the U.S. Army Corps of Engineers and key cooperators initiated an extensive and long-term assessment of potential shoreline damages due to fluctuating lake levels along the Lake Michigan shoreline. It is dedicated to meeting several of the recommendations that came out of the 1986-93 International Joint Commission (IJC) Great Lakes Levels Reference Study.

Specifically, the Levels Reference Study recommended that the economic value of all shoreline interests be objectively assessed in terms of “potential damages”, that being those damages that could occur under differing hydrologic conditions or alternate management approaches to water level controls. This recommended approach differs from previous “damage surveys” conducted in the 1970s, which were limited to actual losses which occurred under a specific extreme lake level condition. The Lake Michigan study is expected to look at potential damages that could occur if water levels continue within the ranges that they have exhibited over the last 120 years or so or whether they would be significantly higher or lower due to climatologic variability or alternate regulation strategies.

The IJC study also had several other recommendations that the Lake Michigan Potential Damages Study is attempting to address. These include initiation of coastal erosion monitoring programs, updating of coastal process research, updating of land use information, and developing effective public information programs.

The planned study of Lake Michigan shorelines is expected to be the first of a long-term initiative of assessing the potential damages along all of the U.S. Great Lakes shorelines. Lake Michigan was chosen to be the first since it has severe erosion problems and was the highest damaged lake during the previous high water periods in the 1970s and 1980s. It is expected that the methodology developed for the Lake Michigan study will be applied to the other Great Lakes so that a consistent approach is taken to the basin as a whole. Many efforts undertaken for Lake Michigan will be directly applicable to other lakes and economies of scale in some work items will lead to basin-wide analyses. In fact, several of the tasks outlined under the Lake Michigan study have been implemented for new analyses of Lake Ontario coastal erosion processes.

The study on Lake Michigan was first focused on five “prototype” counties—three in Wisconsin and two in Michigan. Methods will be developed and refined on the five prototype counties and potential damages will be calculated. The methods will subsequently be applied to the remaining 29 shoreline counties on Lake Michigan.

Study participants have included the U.S. Army Corps of Engineers, other U.S. federal agencies, international and regional entities (IJC and Great Lakes Commission), state agencies (Illinois, Indiana, Michigan and Wisconsin), and academic institutions.

Potential damages will be assessed for all affected shoreline interests including residential property, commercial-industrial-institutional facilities, manufacturing and shipping, retail and other commerce, parks and recreational facilities, commercial fishery, and recreational boating and sports fishery. Community-based impacts such as tourism, water supply, wastewater treatment, dredging, channel maintenance, and structural protection will be evaluated. Environmental effects of extreme fluctuations will be briefly addressed, including impacts on fisheries, habitat diversity, endangered and threatened species and archaeological and special natural features.

The first two years of the study focused on developing the study plan, collecting coastal

erosion data and development of erosion/recession processes modeling and GIS database development. Aerial photography was collected; elevation models, detailed planimetric mapping and land use updates were generated; and comprehensive GIS design was completed. The GIS will be an integral part in forthcoming economic analyses and for public presentations.

In 1999, further investigations were performed that will support the economic analysis. Tasks included developing geologic water level analysis, alternative hydrologic scenarios, planning horizon implications, bluff line mapping, land use trends and updates, deep water wave climate, surge runup characteristics, backwater profiles, shore protection trends, bluff stability analysis, and recession rate analysis. In 2000, potential damage calculations in the five prototype counties were begun. These will be finalized in early 2001. Progress is already being made on collecting critical data for the remainder of the lakeshore counties. In 2001, efforts will focus on collecting data in Berrien, Van Buren, and Muskegon counties in Michigan, and Kewaunee, Milwaukee, Kenosha, and Racine counties in Wisconsin.

Draft Report Outline

Background

Objectives

Study Area

Study Scope Limits

- Planning Objectives and Horizons
- Geologic Perspective on Water Level Fluctuations
- Hydrologic and Control Scenarios
- Backwater and Storm Rise Determinations

Economic Approaches

- Development Projections
- Structural Protection Considerations
- Assessed Values and Market Forces
- Avoided Costs
- Future Model Update Procedures

Geographic Information System (GIS)

- Current and Historic Photographic Base
- Current Base Maps
- Elevation Data
- Parcel and Zoning Data

Land Use Investigations

- Current Land Use Conditions
- Land Use Trends and Future Projections

Coastal Process Investigations

- Recession Rate Updates
- Geomorphic Classifications
- Coastal Data Collection
- Erosion Processes Modeling
- Structural Protection Impacts
- Sediment Transport Affects
- Bluff Stability Considerations
- Wave Climate for Damage Assessments
- Recession Rates for Damage Assessments
- Erosion Prediction System
- Wave Runup Prediction System

Draft Report Outline (continued)

Potential Damage Assessments

- Residential Property Impacts
- Commercial-Industrial-Institutional Impacts
 - Manufacturing and Shipping
 - Retail and Other Commerce
 - Parks and Recreational Facilities
 - Commercial Fishery
- Recreational Boating and Sports Fishery
- Community-Based Impacts
 - Roads and Infrastructure
 - Tourism
 - Water Supply and Wastewater Treatment
 - Dredging and Channel Maintenance

Social Impacts

- Current Land Use Management Practices
- Alternative Land Use Management Options

Environmental Impacts

- Archaeological and Special Natural Features
- Habitat Biodiversity
- Fisheries
- Endangered and Threatened Species

Recommendations and Future Directions

Task List

- 1.0 Study Management
- 1.1 Update Study Objectives and Scope
- 1.2 Organize Study Team and Reviewers
- 1.3 Update Task List and Cost / Time Estimates
- 1.4 Produce Web Pages and Reports

- 2.0 Water Level Scenarios
- 2.1 Document Geologic Perspective of Water Levels Fluctuations
- 2.2 Develop Potential Alternative Hydrologic Scenarios
- 2.3 Develop Potential Alternative Control Scenarios
- 2.4 Develop Deepwater Wave Climate for Each Scenario
- 2.5 Determine Surge / Runup Characteristics for Each Scenario
- 2.6 Determine Estuarine Backwater Effects

- 3.0 Economic Approaches
- 3.1 Assess Planning Horizon Implications
- 3.2 Inventory Shore Protection and Trends
- 3.3 Develop Avoided Cost Considerations
- 3.4 Develop Assessed vs. Market Value Protocol
- 3.5 Develop Future Model Update Procedures

- 4.0 Geographic Information System (GIS)
- 4.1 Design and Update GIS Structure
- 4.2 Coordinate Development of Digital Orthophoto Base
- 4.3 Register Historic Photography
- 4.4 Coordinate Development of Base Maps
- 4.5 Facilitate Development of Digital Parcel Mapping
- 4.6 Collect and Consolidate Elevation Data

- 5.0 Land Use Investigations
- 5.1 Update Current Land Use Mapping
- 5.2 Estimate Development Trends

- 6.0 Coastal Process Investigations
- 6.1 Analyze/Update Existing Shoreline Recession Rate Data
- 6.2 Generate New Recession Rate Data
- 6.3 Revise Shoreline Classification Scheme
- 6.4 Collect Erosion Model Field Data
- 6.5 Develop Erosion Processes Model
- 6.6 Analyze Bluff Stability Factors
- 6.7 Analyze Structural Shore Protection Impacts
- 6.8 Analyze Lakewide Sediment Budgets
- 6.9 Develop Nearshore Wave Transformation Procedures
- 6.10 Develop Erosion Prediction System
- 6.11 Develop Wave Runup Prediction System
- 6.12 Estimate Recession Rates for Each Scenario

Task List (continued)

- 7.0 Potential Damage Investigations
- 7.1 Estimate Low Water Losses
- 7.2 Estimate Flooding Losses
- 7.3 Estimate Erosion Losses
- 7.4 Estimate Recreational Boating and Sports Fishery Losses
- 7.5 Estimate Impacts on Dredging and Channel Maintenance Costs

- 8.0 Social Impacts
- 8.1 Update Current Land Use Management Practice Inventory
- 8.2 Assess Alternative Land Use Management Options

- 9.0 Environmental Impacts
- 9.1 Archaeological and Special Natural Features Impacts
- 9.2 Habitat Biodiversity Impacts
- 9.3 Fisheries Impacts
- 9.4 Endangered and Threatened Species Impacts

Task Breakdown

1.1 Determine/Update Study Objectives and Scope

Objectives: The objectives of the Lake Michigan Potential Damage Study (LMPDS) is to create a modeling procedure for estimating economic effects of lake level changes and related social, environmental, and cultural consequences. The LMPDS modeling approaches are expected to be the framework for economic assessments for each of the other Great Lakes. The LMPDS is also intended to be a forum for concerted information system development between international, federal, state, county, township, and municipal governance about the resource base that is commonly shared. The LMPDS will address all economic factors in the coastal zone surrounding Lake Michigan, including coastlines, embayments, interconnected lake bodies and rivers directly affected by the ranges of water levels defined in the study. Economic effects will be assessed for residential, commercial, industrial, institutional uses and will include recreational boating, municipal water supply and wastewater treatment, and for navigation within the confines of the coastal zone. Environmental and societal consequences of lake level fluctuations will be addressed, albeit in an extremely abbreviated fashion due to finite resources.

Timelines: Most key facets of the study have been coordinated with and agreed to by the study participants to date. It is recognized that an ongoing review of the scope of work will need to continue throughout the lifespan of the study. This is necessary since the level of complexity (or detail) of the study is dependant upon the types and extent of the results accomplished for various study tasks. Continual review of the study scope is also necessary since overall limiting forces (available manpower, funding, and time and other mandates) can change over time.

Personnel Requirements: The development of the study objectives and scoping will be predominately accomplished by USACE, Detroit District personnel. Critical input is expected to be provided from staff of the USACE Great Lakes Regional Office (GLRO) and Waterways Experiment Station (WES), International Joint Commission (IJC), Environment Canada (EC), other U.S. and Canadian federal agencies and, of utmost importance, from input from staff of participating state agencies and academic institutions. Further, the development of a sound economic assessment of the broad impacts of lake level fluctuations will be reliant upon the input of local authorities, whenever possible.

Quality Control: Review of the management of the overall study will be exercised by the USACE, GLRO and by IJC staff.

Accomplishments to Date: Study objectives were coordinated with study team and advisory group members at three meetings (November 1996, January 1997, and September 1997) in the early planning stages. Progress meetings have been held annually to review the previous year's progress and establish goals and direction for the upcoming year. Progress meetings were held in October 1998, November 1999, March 2000, and November 2000.

Future Products: Coordination activities with the study team and associated advisory members will continue throughout the study timeline. The role and utility of the study's products for emerging IJC requirements for review of the Lake Superior regulation plan will likely have direct and material impact on the objectives of study activities

Task Breakdown

1.2 Organize Study Team and Reviewers

Objectives: The objectives of this task are to determine key personnel required to make recurring decisions on the scope of study activities and on the allocation of resources. At a minimum, the study team is expected to include key management personnel from the agencies directly responsible for the completion of the study. An advisory body including staff members from other federal agencies, affected state organizations, and academic institutions will be maintained to review and comment on study approaches, activities, results, and recommendations. Additionally, regional, county, township, and municipal interests will be asked to review key facets of the study, whenever appropriate.

Timelines: The initial organization of the study team was completed in early 1997; the advisory body and extended reviewer lists have been continually maintained, updated, and refined throughout the study.

Personnel Requirements: The current study team includes the following individuals:

<u>Name</u>	<u>Organization</u>
Roger Gauthier	USACE, Detroit
Scott Thieme	USACE, Detroit
Jim Selegan	USACE, Detroit
Marie Strum	USACE, Detroit
Joan Pope / Jack Davis	USACE, WES
John Kangas	USACE, GLRO-Chicago
Ralph Moulton	Environment Canada
Doug Wilcox	USGS

Quality Control: Quality control will be exercised via periodic input provided by IJC staffers, senior USACE staff, representatives from other federal agencies, state organizations, and academic institutions, along with reviews from regional, county, township, and municipal interests.

Accomplishments to Date: The study team and advisory group met six times at the Detroit District's offices--in November 1996, January 1997, September 1997, October 1998, November 1999, and November 2000. Study plans have been reviewed and endorsed, year 2001 tasks have been determined and contracted.

Future Products: Products from these activities include a coordinated plan of study, periodic study reports, and a comprehensive final report.

Task Breakdown

1.3 Develop/Update Task Lists and Cost / Time Estimates

Objectives: This task is dedicated to the planning and management of the LMPDS throughout the study period. Included under this heading are the initial drafting of individual task statements, assessments of time and cost estimates, and programming and allocation of requisite funding.

Timelines: Although this task has particular importance for the first year of the LMPDS, it will be maintained and updated on a semi-annual basis throughout the study period to insure timely and effective project management.

Personnel Requirements: Development and update of the task listings is expected to involve key members of the study team, with input provided on a recurring basis from advisory members and contractor staff.

Quality Control: Review of project tasks and time / cost estimates will be provided by each member of the study team, by the members of the larger advisory / review body of state, academic and local contributors.

Accomplishments to Date: An initial project outline and task list were developed, along with associated timelines and estimates of required manpower and funding for the initial phase of the study, 1997-1998. The plan of study was last revised in April 2001 to update the document on tasks completed to date and establish a course of action for future tasks.

Future Products: The task listing will continue to be updated throughout the study. It will be used as the basis for the final report of the study.

Task Breakdown

1.4 Produce Web Pages and Reports

Objectives: This task is necessary to insure documentation of activities throughout the duration of the study and for enhancing communication between participants and other interested agencies and individuals. Reporting will include the development and update of Internet web pages to facilitate both timely and broad information exchange. A final report for the study should be completed at the culmination of all study tasks to ensure that study objectives, problems encountered, methods and techniques, results, and recommendations are fully documented. Interim progress reports will summarize the progress in a timely manner.

Timelines: Interim progress reports will provide a summary of study progress. The first progress report summarized activities from 1996-98. The second progress report summarized activities in 1999. A progress report for Year 2000 activities will be produced in early 2001. Progress reports will continue to be produced on an annual basis until the project is finished and a final report is produced. An internet web site for the project continues to be updated with study documents and information.

Personnel Requirements: Reporting will be managed by USACE, Detroit District staff with assistance from contractors. Christian J. Stewart Consulting will maintain the web pages and compile the progress reports.

Quality Control: Review of the management of the overall study will be exercised by the USACE, GLRO, and by IJC staff. Reports are circulated to the entire project team, including contractors, for review and comment.

Accomplishments to Date: The first progress report was produced in early 1999 summarizing activities from 1996-1998. The second progress report was produced in early 2000 and summarized activities during 1999. The Year 2000 progress report will be produced in early 2001. An internet web site for the project was created in 1998 and has been updated regularly since then.

Future Products: Annual progress reports will continue to be produced until the study is complete. Final reports for each county will be prepared as the work is finished in each county. The internet web pages were migrated to a USACE Detroit District site in early 2000 and will continue to be updated by contractor.

Task Breakdown

2.1 Document Geologic Perspective of Water Level Fluctuations

Objectives: The objective of this task is to gather information on the geologic history of Great Lakes water levels, as compared to the recent history of recorded water levels. Evidence exists that historical water levels have been much higher and much lower than what has been experienced in the past 140 years (since water levels have been recorded). Significant work has been performed in this area (i.e., Thompson, IGS, and Larsen, USGS, and others), which needed to be reviewed. Findings of this review were used in the development of hydrologic scenarios and would be useful for enhancing the understanding of coastal processes.

Timelines: This task was conducted in 1999.

Personnel Requirements: The above task was performed by contract with GLERL. USACE Detroit District staff administered the contract.

Quality Control: Review of this task was performed by the USACE and by other study team and advisory group members.

Accomplishments to Date: A workshop on Paleo-Lake Levels was held in April 1999. The workshop brought together some of the foremost geologic, climatologic, and hydraulic experts in the U.S. and Canada. Presentations were made of geologic and hydrologic research being conducted by these experts and significant discussions were held regarding the potential future range of levels on the Great Lakes. GLERL produced proceedings of the workshop. The proceedings were made available on the project web site and were summarized in the 1999 Progress Report.

Future Products: This task is complete.

Task Breakdown

2.2 Develop Potential Alternative Hydrologic Scenarios

Objectives: The objective of this task is to generate a series of alternate hydrologic scenarios based upon water supply sequences for each of the Great Lakes. The scenarios would generally represent similar conditions as seen in the recent past and plausible extreme conditions over the near future. These scenarios would need to include monthly mean water levels for each of the Great Lakes over the 50-year planning horizon of the Lake Michigan Potential Damage Study.

- Existing recorded ranges on each lake, with similar frequencies of recorded extremes:
- Existing recorded ranges on each lake, with increased frequencies of extremes:
- Increased extremes in high water levels on each of the lakes, with an increase in the frequencies of high water levels on each:
- Increased extremes in low water levels on each of the lakes, with an increase in the frequencies of low water levels on each;
- Increased extremes in both high and low water levels on each of the lakes, with an increase in frequencies of extremes for both high and low water conditions.

Timelines: This task was performed in 1999.

Personnel Requirements: The above task was performed by contract with GLERL. USACE Detroit District staff administered the contract.

Quality Control: Review of this task was conducted by USACE and by other study team and advisory group members.

Accomplishments to Date: This task was completed in 1999. Five water level scenarios were developed for each Great Lake. GLERL summarized the analysis in a final report. USACE Detroit District staff used the GLERL scenarios to determine a plausible extreme low and high still water level and plausible extreme high, high and low, low scenarios. The GLERL report was made available on the project web site. The entire task, including USACE's analysis, was also summarized in the 1999 Progress Report.

Five water level scenarios were developed for Lake Michigan. Three scenarios--extreme high levels, extreme low levels, and a base case (which is similar to recorded history)--will be used to determine damages in the prototype counties in Task 7. Each scenario consists of a 50-year period of still water levels. Baird & Associates will overlay a storm surge/drawdown scenario on each 50-year stillwater record.

Future Products: This task is complete.

Task Breakdown

2.3 Develop Potential Alternative Control Scenarios

Objectives: This task was designed to develop alternative regulation plans for the control of water levels on Lakes Superior and Ontario. This task is on indefinite hold.

Task Breakdown

2.4 Determine Deepwater Wave Climate for Each Scenario

Objectives: The objective of this task is to develop deepwater wave climates around Lake Michigan for each of the five alternative water level scenarios being assessed. This information is required as input for hydrodynamic, erosion processes, and flood inundation modeling activities.

Previous efforts completed by Baird and Associates included utilizing the wave information system (WIS) historic database covering the period 1957 to 1997 and transferring this information to a nearshore depth of 8 to 10 meters at all of the study sites.

Historic monthly wave energy will be compared to average monthly lake levels at representative locations around the lake (including bays) to determine the most likely wave conditions for each of the alternate hydrologic scenarios. In cases where no significant correlation between lake levels and wave energy can be found, random selection of monthly or yearly wave conditions will be used to build a possible future wave climate for each of the water level scenarios. The Flood and Erosion Prediction System (FEPS) developed by Baird & Associates in 1998 will be used to complete these tasks.

Timelines: This task was begun in 1999.

Personnel Requirements: Baird & Associates was contracted to perform this task.

Quality Control: Review of this task was being conducted by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: In 1999, Baird & Associates compared the historic monthly wave energy to average monthly lake levels at representative locations around the lake. The analysis found that on the west side of the lake in particular, there was a definite correlation between periods of rising lake level and rising wave energy. WIS data was found to be unreliable on the west side of the lake. Baird created its own hindcast of wave data at the WIS locations in order to develop the deepwater wave data.

Future Products: For the five prototype counties, the deepwater wave climate data will be added to storm surge/drawdown hourly values. Then, a random generation of monthly mean stillwater values for each scenario will be added to the wave & surge/drawdown data to generate a set of 50 years of data to use in the FEPS model. This task was completed for the five prototype counties in 2000. WES will continue to develop WIS data for the remaining Lake Michigan counties in 2001 and 2002.

Task Breakdown

2.5 Determine Surge / Drawdown Characteristics for Each Scenario

Objectives: The objective of this task is to estimate storm surge and drawdown characteristics for each water level scenario for each reach of the Lake Michigan shoreline. This information is required as input for the erosion processes modeling to estimate potential damages under different water level regimes.

For historic conditions, measured surge levels are derived through analysis of water level gage records. These analyses typically look at the maximum difference between an instantaneous reading at a particular gage and the monthly mean water level (stillwater) for the lake. For alternative scenarios developed under Tasks 2.2 and 2.3, wave climate and storm surge predictions generated under Task 2.4 will need to be applied to estimate frequencies and magnitudes of storm surges in the nearshore zone.

Timelines: This task was begun in 1999, but delayed due to the delay in obtaining SHOALS data. This task was completed for the five prototype counties in 2000.

Personnel Requirements: This task is being performed by Baird & Associates, with USACE review and administration.

Quality Control: Review of this task is being performed by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: In 1999, historic storm surge and drawdown data were developed for several sites on Lake Michigan. Hourly water level data from 1970 to the present were used in the analysis. A data set of "differences" was obtained by subtracting hourly data from monthly means.

Future Products: Wave heights and storm surge/drawdown will be applied to random values of monthly means for each of the five water level scenarios. These datasets will be incorporated into the FEPS model. This analysis is complete for the five prototype counties, but must be performed for the remaining counties at a future date.

Task Breakdown

2.6 Determine Estuarine Backwater Effects

Objectives: This task is designed to assess the backwater effects associated with high and low hydrologic scenarios for each of the estuarine systems along the Lake Michigan shoreline. There are many areas that are influenced by the water levels in Lake Michigan. It is the intent of this task to determine the upstream limits of these impacts, as well as their spatial extent along the rivers. A wide variety of interest groups exist in these areas such as, riparian homeowners, recreational facilities, industrial facilities, and public infrastructure, among others.

Four river systems were selected for analysis: the Grand River at Grand Haven, Michigan; the Kalamazoo River at Saugatuck, Michigan; the Macatawa River at Holland, Michigan; and the Sheboygan River at Sheboygan, Wisconsin. For each river system, the upstream limit of study was determined. The upstream limit of study is defined as the distance upstream where Lake Michigan backwater effects no longer influence inundation levels or the location upstream where projected land use development (and associated potential damages) no longer exists.

Timelines: This task was completed for the five prototype counties in 1999.

Personnel Requirements: This task was performed for the five prototype counties by Wade-Trim. USACE, Detroit staff provided contract administration and project management.

Quality Control: USACE (Detroit District, WES, and the GLRO) and other study team and advisory group members reviewed this task.

Accomplishments to Date: A memorandum summarizing the results of this study was delivered to USACE. The memo was posted on the project web site and summarized in the 1999 Progress Report. The memo concluded that the 500-year flood elevation closely approximates the Extreme High water level scenario developed in Task 2.2. The memo also concluded that no further backwater modeling or analysis would be necessary. The Extreme High water level was mapped as approximating the 500-year flood inundation from Flood Insurance Study maps. The memo recommended that the Extreme Low water level limits of study be determined by the intersection of the Extreme Low Lake Michigan water level with bathymetric contour data.

Future Products: This task only produced mapping for an approximate Extreme High condition. In order to map the precise Extreme High inundation extent and to be able to map an intermediate elevation (i.e., 100-year water elevation), better topographic maps (with a contour interval of 1-2 feet) were necessary. Existing photography can be used to obtain 4-foot contour intervals at best. A LIDAR survey of three drowned rivermouth areas in the two Michigan prototype counties was conducted in April 2000. This produced a high-resolution topographic map of the land surrounding the drowned rivermouths. One-foot contours were drawn and will be used to define the extent of flooding impacts.

USACE Detroit District obtained better definition of the river mouth bathymetric data in 2000. The SHOALS data was not available for the river mouths due to the turbidity of the water and hydrographic survey of the river mouths was not feasible. NOAA navigation charts were used as the source of bathymetric data. This data will be used to define the extent of low water impacts and in assessing impacts at various low water levels.

Task Breakdown

3.1 Assess Planning Horizon Implications

Objectives: Under this task, the implications of using a 50-year planning horizon for the potential damage estimates for the five prototype counties will be assessed. Selection of a 50-year value for estimating anticipated future losses heretofore has been arbitrary. Considerable debate can occur about the legitimacy of forecasting economic conditions even beyond 4-5 years into the future, although public investments in hazard damage reduction require reasonable estimates of annualized costs and benefits over a longer future time span. Local economic decision-making is highly susceptible to regional, national and even international factors. Land use trends, construction of shore protection and changes in riparian uses all can significantly affect the reliability of estimates of costs and benefits. The life span of structural protection measures also varies considerably by type. The degree of maintenance on these structures can profoundly impact economic estimates. Land use management practices, such as setback restrictions, vary considerably from state-to-state and over time.

The objective of this task is to investigate the implications of using a particular time horizon on the utility of the economic estimates for all inevitable uses. In addition, other planning horizons need to be identified and compared to the implications of using a 50-year horizon. Finally, a recommendation for an appropriate planning horizon for this study will be made.

Timelines: This task was performed in 1999.

Personnel Requirements: This task was performed by P&ZC, under contract with WT/NTH joint venture. USACE provided contract administration and review.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: P&ZC prepared a report summarizing the findings of this task. The report was posted on the project web site and a summary was included in the 1999 Progress Report. The report presented the pros and cons of various time frames for the ultimate uses of the potential damage estimates (e.g., installing shore protection, regulatory, dredging, public facility construction, and residential impacts). The report recommends that a time frame be selected that meets most users needs. This could be a short term (1-5 years), medium term (20-30 years), or long term. Conversely, a fixed point in the intervals could be selected (i.e., 5, 25, 50 years).

Future Products: This task is complete. The 50-year planning horizon will be used in this study.

Task Breakdown

3.2 Inventory Structural Protection and Trends

Objectives: The objective of this task is to estimate future structural protection trends along each reach of shoreline in each of the five prototype counties for each of the five alternate water level scenarios. The shoreline classification database currently includes an inventory of shoreline protection type, level of performance and spatial coverage based on a review of 1997 aerial photography. Shore protection is being constructed all the time. Introduction of new shore protection will influence the future predictions of erosion damages.

Timelines: This task was performed in 1999.

Personnel Requirements: OTI, under contract to USACE, Detroit District.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: In 1999, OTI inventoried and mapped historic trends in shore protection construction in the 5 prototype counties, with the goal of using this information to predict future trends over the next 50 years.

Future Products: OTI's report partially assesses future structural protection trends by providing insight into historical trends. A detailed assessment of future shore protection construction, costs, and impacts has not been performed.

OTI created an inventory of structural protection in four harbors in the prototype counties in 2000.

Task Breakdown

3.3 Develop Avoided Cost Considerations

Objectives: The influence of changes in water levels as a result of alternate hydrologic scenarios or modifications to the regulation procedures must be assessed in term of alternate costs of structural protection. Baird and Associates developed preliminary estimates of avoided costs for structural protection as part of the 1992 International Joint Commission (IJC) Levels Reference Study.

The following subtasks will be performed:

- 1) assess the response of riparians to both an increase and a decrease in the frequency and magnitude of high lake levels (i.e. there may be more or less pressure for implementation of shore protection);
- 2) assess the costs of higher or lower design crest elevations on the per meter cost to implement shore protection; and,
- 3) assess the effectiveness of likely riparian responses and the consequences thereof (some shore protection will reduce damages, while other types of shore protection may not reduce damages at all or even aggravate damages downdrift; hence, a decrease in erosion losses may not result from an increase in structural protection).

Timelines: This task was begun in 1999 and completed in 2000.

Personnel Requirements: This task was contracted to WT/NTH, with P&ZC as a subconsultant. P&ZC performed the first subtask. Wade-Trim performed the second and third subtasks.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: P&ZC conducted a series of focus group sessions with riparian interest groups. The purpose of the focus groups was to assess the response of riparians to both an increase and decrease in the frequency and magnitude of extreme lake levels.

Future Products: This task is complete.

Task Breakdown

3.4 Develop Assessed vs. Market Value Protocol

Objectives: The market value of property is normally higher than assessed value. In Michigan, the assessed value is supposed to be appraised at half of the market value. The assessed values are readily available through tax assessor records. In this task, a consistent method for translating the assessed values of lands and improvements into market values that can be used to estimate potential damages over the 50-year planning horizon of the study will be developed. The method must be applicable in both Michigan and Wisconsin.

Timelines: This task was originally planned for 1999, but has been deferred.

Personnel Requirements: This task is being conducted as a part of Task 7 by contractor.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: None.

Future Products: This work will be completed as part of the economic assessment in Task 7. It will not be addressed as a separate task.

Task Breakdown

3.5 Develop Future Model Update Procedures

Objectives: The intent of this task is to develop a procedure that will allow the study team to update the potential damage assessment in the future, as data becomes more accurate and/or available.

Timelines: This task is currently not scheduled.

Personnel Requirements: This task is currently unassigned.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: None.

Future Products: No products planned at this time.

Task Breakdown

4.1 Design GIS Structure

Objectives: GIS is an important tool in assessing potential damages. A consistent format for all digital data must be developed and implemented so all team members and contractors are using the same format, coordinate system, projection, etc. To date, data have been developed and delivered in various software systems and formats.

Timelines: This is an ongoing task. Some work has been conducted previously, but effort continues.

Personnel Requirements: GRW and OTI have had involvement in this task to date. In year 2000, OTI converted previous recession rate mapping from QuikMap to ArcView format.

Quality Control: USACE (Detroit District, WES, and the GLRO) and other study team and advisory group members reviewed work on this task.

Accomplishments to Date: Many GIS products have been developed. In 2000, these products were brought into a consistent format and data structure for use in Task 7. Orcatec renumbered reaches in the five prototype counties using more recent and detailed mapping information.

Future Products: Ongoing work by USACE Detroit District staff to assemble ArcView projects by county.

Task Breakdown

4.2 Coordinate Development of Digital Orthophotography

Objectives: New, high-resolution digital orthophotos will be developed in the five prototype counties and, subsequently, for the remaining Lake Michigan counties. These photos will be used in subsequent tasks to develop bluff line mapping, to map structures, to update land use mapping, and to be used as a base map.

Timelines: Michigan prototype counties completed in 1999.

Personnel Requirements: This task was conducted by GRW under contract with the Detroit District.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Digital orthophotos, created at 1"=200', were created for the two Michigan prototype counties from photography flown in 1999. Recent digital orthophotos for the Wisconsin prototype counties and other coastal counties in Wisconsin were coordinated by the University of Wisconsin.

Future Products: Digital orthophotography will continue to be developed for the remaining counties in Michigan.

Task Breakdown

4.3 Register Historic Photography

Objectives: Aerial photography of the coastline in the prototype counties is available dating back to the late 1930s. The photography is useful as a second measure of bluff line recession. This task will consist of gathering historic photos of the shoreline in the five prototype counties, registering the photos to the digital orthophoto base maps, delineating a bluff line on each photo, and calculating the recession rate between each historic photograph.

Timelines: This task will be performed in all five prototype counties in 2000 and 2001.

Personnel Requirements: Western Michigan University is contracted to perform the work for the two Michigan prototype counties. The University of Wisconsin will be contracted to perform the work in the three Wisconsin prototype counties.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Historic top of bluff was delineated for several historic periods in 2000. This work will be completed for all five prototype counties in 2001.

Future Products: For each prototype county, historic photos will be used to develop independent recession rates. The recession rates will be used as an independent check on the recession rate data base and model predictions. Depending on the success of this task, it may be expanded to the remaining counties on Lake Michigan.

Task Breakdown

4.4 Coordinate Development of Base Maps

Objectives: High resolution, current base maps are needed in the prototype counties to provide an accurate bluff line delineation and structural inventory for support of other tasks. Top of bluff, toe of bluff, shoreline structure, residential and commercial structures, roads, rivers, lakes, and forested areas will be delineated on the base maps.

Timelines: Bluff line mapping was completed for both Michigan and Wisconsin prototype counties in late 1999/early 2000.

Personnel Requirements: This task was contracted to GRW. USACE Detroit District administered the contract.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Final bluff line mapping has been delivered to USACE Detroit District.

Future Products: Base map development will continue for the remaining Lake Michigan counties. Berrien County mapping will be conducted in 2001.

Task Breakdown

4.5 Facilitate Development of Digital Parcel Mapping

Objectives: Digital parcel mapping will facilitate the calculation of potential damages that are caused by flooding, erosion, and low water impacts. Digital parcel mapping in a GIS environment can be overlaid on the base mapping, the projected bluff line retreat, and the high water mapping. Digital parcel mapping that is linked to the tax roll database will provide a value to each parcel that will be used in the potential damage calculations.

Results from future land use projections can be integrated into the parcel mapping to project future land uses and thus, future damages.

Timelines: This work is scheduled for 2000-2001 for the prototype counties.

Personnel Requirements: The work will be performed by the University of Wisconsin and Western Michigan University, under contract to USACE, Detroit District.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: The University of Wisconsin has gathered digital parcel mapping data for Manitowoc and Sheboygan Counties. Ozaukee County should be completed in early 2001. Western Michigan University completed digital parcel mapping for Allegan County in 2001. Ottawa County is currently conducting their own mapping project. They expect to be complete in 2001. Mapping is now complete, registered, and linked to digital tax roll database for three of the five prototype counties.

Future Products: Digital parcel mapping data linked to tax roll database for all prototype counties to be completed in 2001. Future efforts will focus on the remaining Lake Michigan counties. In 2001, the University of Wisconsin will focus on southeast Wisconsin counties and Kewaunee County.

Task Breakdown

4.6 Collect and Consolidate Elevation Data

Objectives: High-resolution bathymetry data is necessary for refinement of the FEPS model and for determination of high water and low water damages. Data will be obtained through a combination of SHOALS survey, hydrographic survey, topographic LIDAR data collection, and the use of NOAA navigation chart bathymetry.

Timelines: The SHOALS work was begun in late 1999 and was delivered to USACE Detroit District in February 2000. Topo LIDAR work in the river mouth areas in the Michigan prototype counties was completed in 2000. Hydrographic surveys will be performed in the Spring of 2001.

Personnel Requirements: SHOALS surveys were performed by USACE Mobile District. Hydrographic surveys will be contracted to USACE Detroit District contractor. LIDAR work was contracted to EagleScan, as a sub to GRW.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: SHOALS data that were delivered to USACE Detroit District fell short of expectations. Coverage is spotty. LIDAR survey data for topography in the drowned river mouths in 2000 was performed with good success. Bathymetry was defined using digitized NOAA navigation charts in 2000.

Future Products: In 2001, a hydrographic survey will be conducted in six harbors on the Michigan side of Lake Michigan. In addition, a SHOALS survey will be conducted to fill in the data gaps from the 1999 survey.

Task Breakdown

5.1 Update Current Land Use Determinations

Objectives: Land use mapping is available from MIRIS (1988) in Michigan and Current Use Inventory (1978) in Wisconsin. Both are about 10-20 years old, and thus require updating. The recent aerial photography is a good source of data to update the land use. Land use will be updated using recent aerial photography. In addition, a change detection analysis between the 1978/1988 land use mapping and current land uses.

Timelines: This task will be completed in 2001.

Personnel Requirements: The work will be performed by the University of Wisconsin, Western Michigan University, and Grand Valley State University under contract to USACE, Detroit District.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: In the Michigan counties of Ottawa and Allegan, land use has been updated to 1997 for the shoreline townships. A change detection analysis was performed between the 1977 and 1997 land use to determine the patterns in land use change over the past 20 years. The land use update and change analysis was also conducted for the Wisconsin prototype counties. This will help in projecting land use trends over the 50-year planning horizon.

Future Products: Detroit USACE has contracted for the development of new land use mapping for shorelines in Emmet, Charlevoix, and Antrim counties. This work will be complete in 2001.

Task Breakdown

5.2 Determine Land Use Trends and Future Projections

Objectives: This task will include acquiring, reviewing, and evaluating all relevant planning documents (e.g., master plans, zoning ordinances, etc.) for each of the five prototype counties for all areas that could be affected by the range of water levels being examined in this study. Future land use projections for 2020 and 2050 will be made for each of the alternate hydrologic scenarios. These projections will be made for the immediate open lake shoreline and all properties immediately adjacent to interconnected waterbodies upstream to the limit of backwater effects.

Timelines: This work was performed for the five prototype counties in 1999.

Personnel Requirements: Preliminary work was conducted in 1999 by Wade-Trim. Follow-up work will be completed by PZC in 2001. USACE Detroit District is administering the contract.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: A preliminary report for two counties was completed by Wade-Trim in May 2000. PZC will continue this work in 2001.

Future Products: Future land use will be projected for the five prototype counties in 2001. This task will assess how this information could be refined and incorporated into the economic damage assessment.

Task Breakdown

6.1 Analyze Existing Shoreline Recession Rate Data

Objectives: The objectives of this work include the three sub-tasks listed below.

Determine the completeness of existing recession rate data contained in the Detroit District, USACE database for modeling future recession / erosion losses. This sub-task included examination of existing data for each kilometer segment along the Lake Michigan shoreline, particularly for coverage of short-term rates over recent periods of high (1970s, 1980s, and 1990s) or low (1960s) Great Lakes water levels. All recent recession rate data were incorporated as appropriate and mean recession rates and short-term trends were computed and documented.

Evaluate the completeness of the recession rate dataset in context with current land uses, land use trends, and ownership. This sub-task identified newly developed areas, and areas of likely future development, that require improved knowledge of recession rates that have not yet been generated. This work was conducted by performing interviews with county planning officials and reviewing available master plans and other related information.

Determine kilometer segments that have critical need for further recession rate determinations. This sub-task includes the generation of logic diagrams to assist in prioritization of areas where existing data need to be revised to address gaps in the historic record and where new data are needed to address current and/or future development.

Timelines: The above sub-tasks, including completion of a task report, were completed in 1997; some minor follow-up work will continue under this task through June 1999.

Personnel Requirements: These tasks were performed primarily by Christian J. Stewart of VGI Vision Group International Inc. Staff time of the USACE--Detroit District and WES--provided contract administration, technical input, and review of the contractor's work.

Quality Control: Review of these tasks has been exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: New recession rate data were acquired primarily for the Michigan and Wisconsin shorelines through a number of data sources. These data were incorporated into the kilometer-by-kilometer database. Short-term recession rate trends were investigated and reported upon. Land use, land use trends, property ownership and shoreline classification information were incorporated into a database management system named the Recession Rate Analysis System (RRAS). This database was used to identify data gaps and linked to a mapping system for production of user-defined graphics.

Final Products: All tasks were completed and documented in a report and series of data appendices (Stewart, 1997) delivered to the USACE, Detroit in December 1997. This included a fully functional RRAS database. Further updates may occur through the completion of the study.

Task Breakdown

6.2 Generate New Recession Rate Data

Objectives: The objectives of this work include enhancing the completeness of existing recession rate data contained in the Detroit District, USACE databases. This task is focused on filling data gaps in the current record that were identified in Task 6.1, *Analyze Existing Shoreline Recession Rate Data*. New short-term recession rate data will also be generated for critically sensitive shorelines for recent periods of high (1970s, 1980s, and 1990s) or low (1960s) Great Lakes water levels. Long-term average annual rates will be generated for shorelines which were either recently developed or are expected to be heavily developed over the next 50 years. Data from previously undeveloped areas will be important where the erosion contributes significantly to sediment budget in downdrift developed areas. New data will include estimates of the variability of recession rates over time along a particular reach of shoreline. This will be used for determine potential errors in predicting future bluff crest positions due to intermittent or episodic bluff failures.

Initial efforts will be focused on the Green Bay portion of the Lake Michigan shoreline (Marinette, Oconto, Brown and Door counties) in Wisconsin, and the Grand Traverse and Leelanau County shorelines in Michigan as these areas were identified as having significant data gaps.

Focus will also be placed on generating additional recession rate data for differing periods to support work under Task 6.5 *Erosion processes Modeling*. These data are needed to refine and test the model for its subsequent application under Sections 7.0, *Potential Damage Investigations* and 9.0, *Environmental Impacts Assessments*.

Timelines: Initial work under this task was completed in 1998-99. Further work may be conducted at other locales, contingent upon whether or not recession data is critical to economic assessments.

Personnel Requirements: This task is currently being performed by contractor support (Christian J. Stewart -VGI and Rob Nairn - Baird) and/or through cooperative efforts between USACE staff and affected state coastal zone management programs. Updated recession data produced by the States of Michigan and Wisconsin under their on-going mandates were incorporated. This task also requires efforts on the part of USACE staff for contract administration and review of the contractor's work.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Recession rate analysis at the site study areas is complete. A task report was prepared, including kilometer specific data and an updated recession rate database. The updated database includes kilometer normalized long-term average annual recession rates and short-term recession rates for recent high / low lake level periods.

Future Products: A follow-up product will be a GIS software extension to reference recession rate data to other shoreline classification, parcel mapping, and related zoning information. In 2000-2001, independent recession rates will be generated using historic photography. This data will be used to validate/calibrate the FEPS model predictions.

Task Breakdown

6.3 Revise Shoreline Classification Scheme

Objectives: The objective of this task is to develop a revised shoreline classification system enhancing the original scheme developed for the IJC Levels Reference Study. The revised scheme will include better definitions of shoreline characteristics, particularly for the geomorphic characteristics of high bluff environments, subaqueous sediments, and the extent and caliber of structural protection. These changes are necessary to complete work under the erosion processes modeling tasks, including forecasting of future bluff recession rates. The revised scheme is to be applied to the Lake Michigan shoreline wherever shore type boundaries need to be re-delineated. This effort will be field verified.

The revised scheme needs to be appropriate for application to each of the other Great Lakes with minimum modification. The geomorphic classification is needed for sediment budget and slope stability analyses. The subaqueous classification is a key input for driving the erosion processes model. The shore protection classification is needed for both the erosion processes and sediment budget components of the model. A variety of methods and datasets will be used for this reclassification effort, including airborne video collection of the shoreline and use of available lithology, bore hole, profile, and GPR data.

Timelines: The revised scheme and an associated task report were completed in 1997. Application of the revised scheme to Lake Michigan shorelines, including re-delineation of boundaries and field verification is also complete.

Personnel Requirements: The 1997 tasks were performed primarily by Christian J. Stewart of VGI and Rob Nairn - Baird. USACE (Detroit District and WES) performed contract administration and project management. 1998 tasks were completed by a combination of contractor efforts and in-house staff. Detroit District staff onboard U.S. Coast Guard helicopters completed airborne video collection.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and GLRO) and by other study team and advisory group members.

Accomplishments to Date: Coordination has been conducted with key erosion processes experts on several occasions. A revised classification scheme has been developed and has been applied to the Lake Michigan shoreline during a one-week classification workshop. New shoreline statistics have been generated along with associated graphics, which will be detailed in a final report. Completed products from this effort include a revised classification scheme, including the geomorphic, subaqueous, and structural protection characteristics of the Lake Michigan shoreline, re-delineated mapping incorporated into the project GIS, and a final report on the methodologies and results employed.

Future Products: This task is complete.

Task Breakdown

6.4 Collect Erosion Model Field Data

Objectives: The objective of this task is to collect extensive field data at selected study sites, which represent larger areas of similar sandy or cohesive shore types in both developed and undeveloped areas. These data should provide critical information to test and refine analytical procedures outlined under Task 6.5, *Erosion processes Modeling*.

Data need to be collected at the following study sites: Two Creeks, WI; Fisher Creek, WI; New Buffalo, MI; Warren Dunes, MI; Shoreham, MI; Miami Park, MI; Muskegon, MI; and Little Sable Point, MI. These sites were chosen since they are fairly representative of various shore types and levels of development. Some of these detailed study sites were chosen because other data collection efforts took place there in the past, which provide a better understanding of temporal changes.

The types of data collected at each site are as follows: hydrographic and topographic survey lines (one primary line with two parallel secondary lines on either side locating the top and toe of the bluff, shoreline, and profile of offshore bottom elevations to the 20 foot contour); soil borings, elevation of glacial till and its contact with overlying sand deposits, and laboratory tests for engineering properties; geophysical surveys (generally ground penetrating radar) to determine the thickness of sand deposits; and SHOALS (Scanning Hydrographic Operational Airborne LIDAR System) bathymetric surveys from the bluff edge to the 20 foot contour, for a distance of approximately one mile at each study site, centered around the survey lines.

Timelines: These tasks were completed in 1997 and 1998.

Personnel Requirements: The majority of these tasks were performed through contracts. Coleman Engineering performed the Wisconsin field surveys; and Toltest, Inc. performed the Michigan field surveys. SHOALS surveys were performed by USACE Mobile District. USACE (Detroit District and WES) staff time has been required to cover contract administration and documentation of results.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and GLRO), and by other study team and advisory group members.

Accomplishments to Date: All 1997 and 1998 coastal field data collection efforts are complete. Products from this task include: collection, reduction, and reporting of digital data for the SHOALS surveys, and other topographic, hydrographic and geophysical surveys including digital profiles, contour maps, boring logs, and lab test results.

Future Products: Some ongoing sporadic data collection continues, as required for the erosion model.

Task Breakdown

6.5 Develop Erosion Processes Model

Objectives: The objective of this task is to create a model for predicting erosion over a range of time scales from several months to 30 years or more. This information will then be coupled with a GIS to assess economic and environmental implications of significantly different hydrologic scenarios than which have recently occurred. Specifically, the erosion processes model will be developed for describing erosion associated with cohesive and sandy shore conditions of the Great Lakes.

Model development will include linking existing numerical models (wave climate, wave propagation, nearshore erosion processes and bluff failure) and making modifications to produce a versatile model for describing and predicting erosion for short to long-term time scales. The model will be tested at the study sites where the data are to be collected under Task 6.4. The model will be applied basin wide across the Lake Michigan shoreline to estimate the degree that beach erosion and bluff recession would be expected to take place in response to various hydrologic/control scenarios over the planning horizon of the study. This work will be conducted under Task 6.12.

Timelines: This task was conducted over three years (1997-99). Development of the model is complete.

Personnel Requirements: The above tasks were performed primarily by contract with Baird & Associates, Ltd. Staff time of both the USACE (Detroit District and WES) was required for contract administration and for providing input during task execution.

Quality Control: Review of these tasks was exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Work has included refining prior modeling approaches, coordinating design considerations, developing of the conceptual model, and calibration of the model performance against historic water level data at the detailed study sites. Work also included basin-wide model application of the model to the alternative hydrologic/control scenarios and linkages into with the comprehensive GIS framework outlined under section 4.0.

Future Products: The principal product from this task is an operational erosion process model that can simulate anticipated beach erosion and bluff recession rates under a variety of differing lake level and storm frequency scenarios. This model is designed to run at a local level so that county planners and community developers can anticipate likely changes in hazard zones along the shoreline. A report was generated outlining the methods employed, results achieved and recommendation for future applications.

Task Breakdown

6.6 Analyze Bluff Stability Factors

Objectives: The objective of this task is to determine the interdependence between erosion processes and bluff stability. Many erosion processes may influence the stability of bluffs, such as the removal of beach surcharge at the toe of a bluff, notching at the toe of a bluff, and wave impact on the bluff face. Alternatively, bluff stability and ultimately failure can influence erosion processes by obstructing sand transport or protecting the erodible section of a lakebed. Further analysis on these issues must take place to ensure the linkages between bluff stability and erosion processes are incorporated into the erosion processes model being developed under Task 6.5.

Some important work has recently taken place for the Allegan County shoreline by Dr. Bill Montgomery and in the Wisconsin by Drs. Bosscher, Michaelson, and Edil. The geotechnical information being gathered at the site study areas should prove useful in further defining these interactions. This task will likely be highly qualitative drawing upon field observations, research and publications conducted by others outside the scope of this study. This will not be a lakewide function of the model and in most cases will require additional site specific data to apply this procedure. A secondary objective of this task will to assess the duration over which bluff stability is an important influence on recession rate calculations on a lakewide basis. Cross-shore and alongshore variability in stratigraphy will also be investigated.

Timelines: This task was conducted in 1998-99.

Personnel Requirements: This task was conducted under contract with Baird & Associates. Staff time of the USACE, Detroit District and WES is expected to be required for completing contract specifications and negotiations, providing follow-up support during task execution, and reviewing of the contractor's work.

Quality Control: Review of these tasks will be exercised by USACE staff (Detroit District, WES, and GLRO) and from study team and advisory group members.

Accomplishments to Date: The first activity consisted of interpreting and extending the work completed by Dr. David Mickelson of the University of Wisconsin in 1998 to define uncertainty band widths for all possible types of local bluff conditions found in each of the five prototype counties. As a first step in this activity, a review of the existing geomorphic shore classification was undertaken to ensure that it was sufficient (along with bluff height information) to capture shoreline types highly susceptible to deep seated failures.

The second activity consisted of site-specific and short-term investigations of the links between coastal processes and bluff stability. These investigations were completed for the Allegan County, Michigan study sites. These sites were monitored on a bi-weekly basis for a period of three years. Assessments of groundwater conditions have also been completed at each of the sites and along a 24 kilometer reach of the shore. A detailed analysis of wave, erosion and runup conditions at each of the WMU study sites was conducted using the Flood and Erosion Prediction System to refine understandings of the bluff failure mechanisms.

Future Products: Baird is now in the process of developing a comparison of these findings with correlation between uncertainty bandwidth and geomorphic type. The procedure developed under this task will then be applied in erosion damage assessments for the remainder of the Lake Michigan shoreline.

Task Breakdown

6.7 Analyze Structural Protection Impacts

Objectives: The objective of this task is to determine the interdependence between erosion processes and the extent, type and quality of structural shore protection put in place along the Lake Michigan shoreline. Many erosion processes influence the effectiveness of shore protection structures over their design life. Alternatively, structural shore protection has a direct and measurable effect upon alongshore sediment transport interfering with natural processes of beach accretion and erosion. The geotechnical information being gathered at the site study areas may prove useful in further defining these interactions. This study task will likely be qualitative drawing upon field observations, research and publications conducted by others outside the scope of the overall study. Further analysis on these issues must take place to ensure that the erosion processes model being developed under *Task 6.5 Erosion processes Modeling* provides reliable estimates of future erosion and recession. This is especially important for areas where greater capital investment in structural shore protection is expected to occur over the study-planning horizon. The results of this task will be used to define the role of the different types of shore protection structures on erosion processes for the lakewide predictions. It will also be important to evaluate the accelerated erosion that would occur if existing structures were to fail (particularly those that have been subject to considerable nearshore downcutting). In addition to contributing to the assessment of potential damages, another intention of this task would be to develop general guidance on the efficacy of different types of shore protection in different physical settings.

Timelines: This task was initiated in 1999 and was completed in 2000.

Personnel Requirements: This task was contracted to NTH-WT joint venture, with NTH primarily doing the work. Staff time of the USACE, Detroit District and WES is expected to be required for completing contract specifications and negotiations, providing follow-up support during task execution, and reviewing of the contractor's work.

Quality Control: Review of these tasks will be exercised by USACE staff (Detroit District, WES, and GLRO) and from study team and advisory group members.

Accomplishments to Date: A report was submitted by NTH in 2000.

Future Products: Future investigations into the effect of structural protection on erosion processes will be addressed in sensitivity modeling in 2001.

Task Breakdown

6.8 Develop Lakewide Sediment Budget System

Objectives: The objective of this task is to determine a sediment budget, on a lakewide basis, which can be updated to keep track of sediment supply to various reaches around the Lake Michigan shoreline. This analysis would include information for various reaches, such as: potential alongshore transport rates; fraction of beach size sediment made available through erosion; other sources of sediment; and, sinks of sediment. This analysis will provide important information for predicting the sand cover on cohesive shores, and changes, which may effect future recession rates. Essentially, a predictive system will be developed to evaluate changes to sand cover on cohesive shores (or erosion of sandy beaches) where the sediment budget has been influenced by natural or human factors. This will introduce a feedback mechanism in to the modeling system as changes to sand cover may influence recession rates which in turn will influence yield of eroded sand (and sand cover), which in turn effects recession rates. This feedback mechanism will be addressed in the overall erosion prediction system through iterative model runs. It is likely that the fully interactive predictive system involving both sediment budget and erosion processes modules (i.e. complete with feedback) would only be applied on a littoral cell basis (i.e. not on a lakewide basis). It is intended that the sediment budget system for predicting changes to sand cover should be checked against the recent changes that have been experienced downdrift of New Buffalo.

Timelines: This task was initiated in 1999.

Personnel Requirements: The above tasks will be performed under contract with Baird & Associates. Staff time of the USACE, Detroit District and WES will be required for completing specifications for contracting, negotiating work assignments, providing input during task execution, and reviewing of the performance of the contractor.

Quality Control: Review of these tasks will be exercised by USACE staff (Detroit District, WES, and GLRO), and by other study team and advisory group members.

Accomplishments to Date: In 1999, assessments were made of the influence of sediment budget on the evaluation of historic and prediction of future recession rates for each of the five prototype counties. The sediment budget module of FEPS is being applied to complete this assessment. Sediment budget assessments were completed for the historic period of record corresponding to the available recession rate data. Due to the lack of complete SHOALS data at the harbor mouths, complete sediment budget analysis could not be performed. Further data is necessary.

Future Products: This assessment will be used to assess impacts of sediment budget changes on recession rate predictions. Tests of sediment budget outcomes using the FEPS are being completed for each of the alternate water level scenarios to test the influence of different wave and lake level conditions on sand transport rates and sediment budget. The new SHOALS data was insufficient at the harbor mouths. Hydrographic surveys will be conducted to provide the data necessary to complete the sediment budgeting. This work will be completed in 2001.

Task Breakdown

6.9 Develop Nearshore Wave Transformation Procedures

Objectives: The objective of this task is to apply a nearshore wave transformation procedure to determine local wave condition input to the erosion processes model using the deepwater WIS data for various scenarios as input. In many open coast locations this transformation procedure will be straightforward and will incorporate application of the TMA spectral similarity concept in addition to linear wave refraction. However, at some locations (particularly for the lakewide application) more detailed estimates of wave conditions may be required (e.g. for sheltered bays or areas inshore of shoals or islands). Owing to the size of the lake, the simplest possible techniques will be applied to address these complexities. The work conducted under this task is essential to develop input for the erosion processes modeling associated with the detailed study sites investigations and the lakewide applications.

Timelines: This task was initiated in 1997 and completed in 1998. Modifications to address alternate hydrologic regimes, particularly if storm frequencies differ from historic values assessed under Task 2.4 would need to be conducted thereafter.

Personnel Requirements: This task was performed under contract with Baird & Associates, Ltd. USACE (Detroit District and WES) provided time for completing specifications for contracts, providing input during task execution, and reviewing of contractor's work.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Historic surge level data has been interpolated on a lakewide basis and has been estimated for selected study sites along the Lake Michigan shoreline. Baird has also developed time series of monthly vs hourly differential to convert future monthly data (the five scenarios) to hourly data for input to the erosion estimates and has developed a methodology for assessing coastal flooding in the five prototype counties.

Future Products: This task is complete.

Task Breakdown

6.10 Develop Erosion Prediction System

Objectives: The objective of this task is to create the erosion prediction system by linking the various types of input and integrating the various model components. This task also includes developing output formats to maximize on the presentation potential of the generated information.

The input to the system will include the following: recession; water levels and waves; underwater stratigraphy; sand cover thickness or cobble/boulder lag deposits; shore protection; geomorphic (bluff) conditions including bluff height; detailed stratigraphy/groundwater conditions for bluff stability calculations.

The above list of input will be directly linked to the following group of integrated model components. The erosion processes model COSMOS will be used to make estimates of downcutting, toe erosion and shoreline recession. The model will also be used to estimate alongshore transport rates (under both full supply and supply limited conditions) for input to the SEDIMENT BUDGET module; The SEDIMENT BUDGET model will be used to assess human and natural impacts on sand cover for cohesive shores and erosion/deposition trends for sandy shores; A SLOPE STABILITY model will identified as a tool as part of a procedure to evaluate slope stability issues on a site specific basis. This model will not be directly integrated within the lakewide prediction system. WAVE RUNUP is an optional model component in the overall system. The erosion processes model COSMOS could be linked directly to a series of in-house Baird algorithms for prediction of wave runup (using the full range of available techniques). This optional item is described in more detail under the next task description.

Timelines: A mock up of the system was developed in 1998 and 1999. The model was used in 2000 to make preliminary projections of bluff retreat in the five prototype counties. Projections will be refined in 2001.

Personnel Requirements: This task was performed under contract with Baird & Associates, Ltd. USACE (Detroit District and WES) provided time for completing specifications for contracts, providing input during task execution, and reviewing of contractor's work.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: The erosion prediction system setup is complete.

Future Products: The model will be used to predict future bluff crest positions for a given set of conditions. The prediction system will also provide a nearshore sand management tool on a lakewide basis. In addition, the system could be applied on a site specific basis to assess the impact on the probability of bluff failure (or factor of safety) of wave erosion associates with "what if" scenarios.

Task Breakdown

6.11 Develop Wave Runup Prediction System

Objectives: Develop a fourth module for the Shore Erosion Prediction System that will provide an estimate of wave runup (extreme value analysis) on a kilometer reach basis. One option includes using existing Baird software (both the COSMOS erosion processes model and RUNUP software) that could be integrated to produce a predictive system for estimating runup using the range of techniques presently available in the literature. A lakewide definition of wave runup statistics on a kilometer definition for both historic and future scenarios would be a unique tool and one which state and other federal agencies may have great interest.

Timelines: Completed in 1999.

Personnel Requirements: This task was performed under contract with Baird & Associates. USACE (Detroit District and WES) provided staff time for completing specifications for contracts, providing input during task execution, and reviewing of contractor's work.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: An analysis into the correlation between lake levels and wave energy was investigated.

Future Products: The results from this task will be used to complete flooding estimates in the five prototype counties. It will provide a system that can predict runup statistics on a 1 km reach basis for the historic and future water level scenarios.

Task Breakdown

6.12 Estimate Recession Rates for Each Scenario

Objectives: The objective of this task is to generate estimates of future average annual recession rates for each and every kilometer along the Lake Michigan shoreline for each and every one of the hydrologic / control scenarios being evaluated under the overall study. This work is the culmination of most of the coastal investigations being conducted under this study. An initial sub-task will be to check the predicted recession rates for a historic period (covering all or part of the 1956-1996 updated WIS database) against the estimated rates for all reaches. Refinements to the classification system, the wave input and/or the coastal process modeling system may be required to ensure that the model is capable of representing, to a reasonable degree of accuracy, the existing conditions. Once satisfactory results are achieved for all reaches, the system will be applied to predict recession rates for all reaches under the various hydrologic scenarios.

Timelines: This task will be completed for the five prototype counties in early 2000.

Personnel Requirements: This task will be performed under contract with Baird & Associates. Staff time of both the USACE (Detroit District and WES) will be required for completing specifications for contracts, providing input during task execution, and reviewing of contractor's work.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Much effort has gone into setting up the model and collecting all necessary input data. No recession predictions are available to date.

Future Products: A report summarizing recession rates under each hydrologic scenario was developed for the five prototype counties in early 2001.

Task Breakdown

7.1 Estimate Low Water Damages

Objectives: In this task, damages to residential, commercial, industrial, institutional, and community-based land uses under low water conditions (which may occur under any water level scenario) will be calculated. Impacts of low water scenarios could include, but are not limited to, the following:

- loss of structures due to drop in static water level
- increased maintenance costs of private boats (e.g., prop damage)
- loss of use of private and public boat slips and marinas
- impacts on water intakes and wastewater discharge outfalls

Low water damages will be summarized by land use category. Damages will be calculated at the parcel level, if available, and summarized by township and county. Low water damages will be summarized to produce one damage value for each county over the 50-year planning horizon.

Timelines: This task will be conducted in 2000 and 2001.

Personnel Requirements: This task is being conducted by the DLZ/SEG team, including P&ZC and Dr. John Hoehn, an economist from Michigan State University. USACE Detroit District is administering the contract.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Preliminary damage assessments were completed in November 2000 for Allegan County. Work continues on the remaining prototype counties.

Future Products: Potential damages for three water levels scenarios (base case, extreme high, and extreme low scenarios) will be calculated for the five prototype scenarios in 2001.

Task Breakdown

7.2 Estimate Erosion Damages

Objectives: Damages to all land use categories caused by erosion over the 50-year planning horizon will be calculated. The bluff line recession calculated by Baird & Associates will be used as the basis of evaluation to determine the number and type of parcels that will be affected by erosion over the 50-year period.

Erosion impacts could include, but are not limited to, the following:

- loss of property and structures within the bluff line recession zone
- costs of maintenance and repair to shore protection structures

Erosion damages will be summarized by land use category. Damages will be calculated at the parcel level, if available, and summarized by township and county. Erosion damages will be calculated for the cumulative effect over 50 years.

Timelines: This task was conducted in 2000 and 2001.

Personnel Requirements: This task is being conducted by the DLZ/SEG team, including P&ZC and Dr. John Hoehn, an economist from Michigan State University. USACE Detroit District is administering the contract.

Quality Control: Review of these tasks is being conducted by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: Preliminary damage assessments were completed in November 2000 for Allegan County. Work continues on the remaining prototype counties.

Future Products: Potential damages for three water levels scenarios (base case, extreme high, and extreme low scenarios) will be calculated for the five prototype scenarios in 2001.

Task Breakdown

7.3 Estimate Flooding Damages

Objectives: The damages to all land uses will be calculated under flooding conditions that may occur under any of the three water level scenarios. Damages will be calculated for a minimum of two water levels above the riverbank for inland harbor areas (e.g., 100-year and 500-year water levels).

Impacts of flooding could include, but are not limited to, the following:

- loss of structures, if any, caused by flood waters
- loss of commercial income during floods
- costs to communities and private citizens for cleanup and restoration of property

Officials at the local community level will be contacted to obtain information on historical impacts of flooding. Flooding damages will be calculated by event and summarized over the 50-year planning horizon. Damages will be calculated at the parcel level, if available, and summarized by township and county. Damages will also be summarized by land use category.

Timelines: This task will be conducted in 2001.

Personnel Requirements: This task is being conducted by the DLZ/SEG team, including P&ZC and Dr. John Hoehn, an economist from Michigan State University. USACE Detroit District is administering the contract.

Quality Control: Review of these tasks will be conducted by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: LIDAR surveys of three river mouths in the Michigan prototype counties was conducted in 2000. This provides the basis for calculation of flooding damages.

Future Products: Potential damages for three water levels scenarios (base case, extreme high, and extreme low scenarios) will be calculated for the five prototype scenarios in 2001.

Task Breakdown

7.4 Estimate Recreational Boating and Sports Fishery Losses

Objectives: Recreational boating and sports fishery uses could be significantly affected by prolonged extreme low water levels. This task will quantify the losses by scenario.

Timelines: This task was completed for the five prototype counties 2000. The remaining counties will be evaluated in 2001.

Personnel Requirements: This task was contracted to Planning & Zoning Center by the USACE Detroit District. Michigan State University and EPIC/MRA participated in the study also.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: A final report assessing recreational boating impacts in the five prototype counties was completed in early 2001.

Future Products: In 2001, the remaining counties on Lake Michigan will be evaluated. A report is expected in late 2001.

Task Breakdown

7.5 Estimate Impacts on Dredging and Channel Maintenance Costs

Objectives: The impacts of each water level scenario on federal projects will be assessed in this task. Dredging and channel maintenance are two of the critical items. Potential impacts on federal structures will also be addressed.

Timelines: This task was performed in 2000.

Personnel Requirements: This task was performed as a Value Engineering Study, led by the USACE Detroit District, with participation from Baird & Associates and WES. USACE representatives from the Grand Haven, Michigan and Kewaunee, Wisconsin also participated.

Quality Control: The USACE Detroit District and other study team and advisory group members provided review.

Accomplishments to Date: A value engineering study report was prepared that summarizes the potential economic impacts of the three water level scenarios on federal projects in the prototype counties.

Future Products: The VE study report must be evaluated as to its applicability to other federal structures in Lake Michigan.

Task Breakdown

8.1 Update Current Land Use Management Practice Inventory

Objectives: Under Phase 2 of the IJC Levels Reference Study, the USACE contracted for a comprehensive inventory of current land use management practices in the United States shorelines of the Great Lakes. In this task, this prior work will be reviewed and modified accordingly for current conditions employed in Michigan, Wisconsin, Illinois and Indiana. Also, an evaluation will be conducted as to whether other land use management measures currently exist in the five prototype counties that should be included under this inventory.

Timelines: This task was contracted in 1999 and completed in early 2000.

Personnel Requirements: This task was contracted to P&ZC. USACE Detroit District administered the contract.

Quality Control: Review of these tasks was conducted by the USACE Detroit District and by other study team and advisory group members.

Accomplishments to Date: A report was provided to the Detroit District in early 2000.

Future Products: None anticipated.

Task Breakdown

8.2 Assess Alternative Land Use Management Options

Objectives: This task will evaluate likely changes in land use management practices as a direct or indirect consequence of changing conditions that could occur under the alternate hydrologic scenarios. Since these scenarios outline extremes not previously encountered on the Great Lakes, it is expected that governments, communities, and individuals will adapt to their changing environment. This task requires speculation as to whether or not adaptive measures would likely occur that would change the magnitude of economic losses. The product will be a summary report that includes observations, conjectures, and issues of debate that could be factors in further analyses under this study.

Timelines: This task was contracted in 1999 and completed in early 2000.

Personnel Requirements: This task was contracted to P&ZC. USACE Detroit District administered the contract.

Quality Control: Review of these tasks will be conducted by the USACE Detroit District and by other study team and advisory group members.

Accomplishments to Date: A report was provided to the Detroit District in early 2000.

Future Products: None anticipated.

Task Breakdown

9.0 Environmental Impacts

Objectives: Investigation of **environmental impacts** will focus on:

- 9.1 Impacts to archaeological and special natural features;
- 9.2 Impacts to habitat biodiversity;
- 9.3 Impacts to fisheries;
- 9.4 Impacts to threatened and endangered species.

Environmental impacts are an important aspect to consider. This task will rely on literature data, previous studies, and the IJC Levels Reference Study for source material on the expected impacts. A detailed environmental assessment will not be conducted. for use in the LMPDS. This will also be supplemented by anecdotal and personal interview data collected through discussions with county, municipal and other government agency personnel.

Timelines: This task will be conducted in 2001 for the prototype counties.

Personnel Requirements: This task will be conducted by the USGS, with contract administration by USACE Detroit District.

Quality Control: Review of these tasks will be exercised by the USACE (Detroit District, WES, and the GLRO) and by other study team and advisory group members.

Accomplishments to Date: None.

Future Products: This task will produce a memo that summarizes expected general environmental impacts under each water level scenario.